Jupyter Notebooks as an Effective Way to Teach Dynamic Programming

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***Abstract*—An introductory course in dynamic programming was created using Jupyter notebook as the delivery medium.[1] While other Jupyter notebook courses restrict themselves to text, images and inline coding, this course leverages Jupyter features and extensions to include a wider range of interactive course elements such as quizzes. The course combines some best practices in teaching dynamic programming to attempt to overcome the difficulties students experience when learning the subject. The paper also presents the results of a peer survey qualifying the success of this new course.**

1 INTRODUCTION

Dynamic programming was invented in the 1950's by professor of mathematics Richard Bellman to solve problems which have an optimal substructure (Dreyfus, 2002). This means that the optimal solution to a larger problem can be calculated by recursively finding the optimal solution of its sub-problems.

It is considered one of the "sledgehammers of the algorithm craft" (Dasgupta et al., 2008) so called because it is a *general* technique. It can be used on a wider variety of problems than more specialized techniques such as 'divide-and-conquer'.

1.1 A Difficult Subject

It is generally accepted that dynamic programming is a difficult subject for students to grasp. (Enström, 2013, Forišek, 2015). In fact, many algorithm textbooks introduce dynamic programming almost apologetically, like in this caveat from *The Algorithm Design Manual:*

1 Here is the link to the project's GitHub repository

> "[Until] you understand dynamic programming, it seems like magic." (Skiena, 1998)

A review of the literature reveals a few explanations for this difficulty:

Dynamic programming techniques depend on finding a recursive algorithm to solve the problem, and recursive techniques are themselves difficult. (Enström, 2013). Learners who develop non-viable mental models (Norman, 2014), such as the looping model of recursion, are not able to accurately predict the behaviour of recursive functions (Götschi et al., 2003; Sanders et al., 2006; Scholtz & Sanders, 2010). This would make it hard for the student to understand how to construct an optimal solution from sub-problems. Correctly defining bases cases of recursive functions, a key element in developing a dynamic programming algorithm, is also shown by Haberman & Averbuch (2002) to be a difficult concept for students.

1.2 Recommendations

To overcome these difficulties a course in dynamic programming should adopt practices that reinforce a correct mental model of recursion (McCauley et al., 2015) and be designed to teach the subject in a systematic manner (Forišek, 2015).

In addition, the course should follow other best practices in teaching algorithms such as using worked examples (Sweller, 2006), metaphors (Forišek & Steinová, 2013), and animations (Halim, 2015, Végh & Stoffová, 2017).

And finally, in order to reach as wide an audience as possible, the course should be deployed on an easy to access and free platform unlike many MOOCs which are only accessible to learners in affluent countries (Reich & Ruiperez-Valiente, 2019).

1.3 A Better Way

Inspired by the imagery afforded by dynamic programming as 'magic', this project sets out to develop a short course to help students learn the

tricks and practice the art themselves. The course is called 'Magic of Dynamic Programming' (hereafter referred to as MoDP).

The syllabus of the course implements the lesson plan outline laid out in the article '*Towards a better way to teach dynamic programming'* by Forišek, M. (2015). The lesson contents are original, including interactive widget infrastructure purpose-built for delivering non-graded quizzes.

2 RELATED WORK

Most of the classic algorithm textbooks have a section on dynamic programming (Dasgupta et al., 2008, Cormen et al., 2009, Jon. Kleinberg & Tardos, 2006, Skiena, 1998) with each emphasizing a different aspect and choosing different problems as teaching examples (Forišek, 2015). Textbooks tend to be comprehensive but are not accessible to all students, for example *Introduction to Algorithms: A Creative Approach* by (Manber, 1989) makes the valuable connection between mathematical induction and recursion, but the book is not freely available online. Some textbooks are out of print (such as the dynamic programming textbook by Bellman et al., 1970) or simply not engaging enough.

The site *A gallery of interesting Jupyter Notebooks* curated by Goldenberg, Dima lists few Jupyter notebooks teaching introductory algorithms and none teaching dynamic programming.

Hamouda et al., (2019) present an interactive notebook-like teaching tool to overcome students' misconceptions about recursion and encourage practice.

Related work in investigating the effectiveness of including interactive elements in a course, include a study by Kovacs (2016) that shows student engagement with MOOC videos was shown to increase with in-video quizzes.

Many online free resources with worked examples and complete solutions (such as *GeeksForGeeks* Dynamic Programming) have excellent explanations of the algorithms, but the pedagogy is haphazard without any systematic ordering of the worked examples.

Often, implementing algorithms in code can concretize the solution for the learner (Skiena, 1998). Video courses such as MIT OpenCourseware

Introduction to Algorithms (Erik Demaine & Devadas, 2011) are excellent but by their nature do not have algorithm coding practice built in. Other tutorials that do emphasize practice, require users to set up a programming environment. By implementing the course in a Jupyter notebook, this obstacle is removed since learners can code up the algorithms directly in the notebook.

3 THE SOLUTION

"Design your notebooks to be read, run and explored" (Rule et al., 2019)

Wherever possible, the course design and implementation attempted to follow this advice.

3.1 Course Audience

The intended audience for the course is computer science students preparing for an undergraduate or introductory graduate level algorithms course. The course assumes some knowledge but not expertise in: Data structures, algorithm time and space complexity analysis and Python programming language.

MoDP can be thought of as a workshop, with the nine notebooks of the full course designed to be completed over a weekend.

3.2 Course Elements

The notebooks combine a few forms of teaching: The topics are introduced with a short video, the style of the videos following recommendations to pace delivery with handwriting on a board. (Armour et al., 2016, Winston, 2019). Handwriting in videos was not implemented for technical reasons but it was simulated using PowerPoint animation. The problem statement for the worked example is illustrated with a diagram as shown in Figure 1—

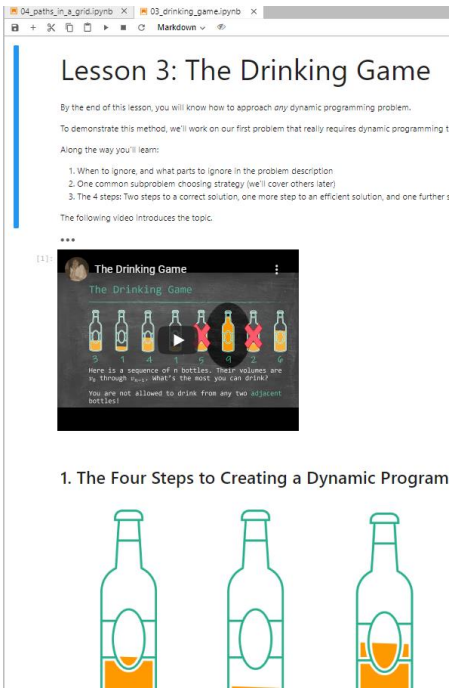

Figure 1 — Embedded video in the Jupyter notebook

The student's understanding of the problem statement is tested with one or more quizzes as shown in Figure 2 —

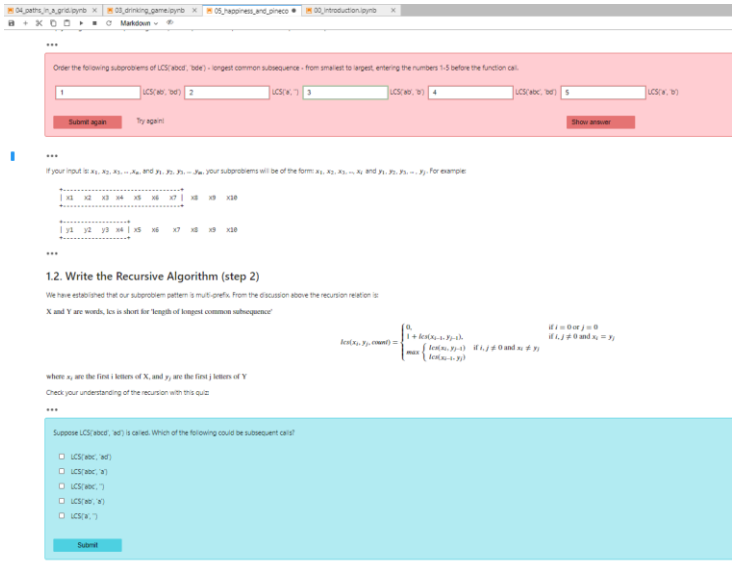

Figure 2 — Embedded quizzes in the Jupyter notebook

Quizzes are designed to give immediate gratifying feedback (Kovacs, 2016). Then the student is given starter code to implement the algorithm on their own (Sweller, 2006). Some of the notebooks contain further practice examples.

Solutions to exercises are supplied (hidden) at the end of each notebook.

Experimentation is encouraged throughout the lessons by the very nature of the notebooks, where code cells can be easily added and ran. The power of magic commands for profiling code (Jake VanderPlas, 2016) is one use of experimentation in this course.

3.3 Tools and Sharing

Quiz infrastructure was developed especially for this project using the Jupyter extensions ipywidgets expanding on the work of Leejy (2020).

As recommended by Rule et al., (2019), the notebooks are under version control in a dedicated GitHub repository

Binder was used as the tool for hosting the Jupyter notebooks (Evans, n.d.) so that users can start learning right away just with a browser and without having to install any environment.

3.4 Lessons

Forišek' (2015) proposes ordering the dynamic programming problems that are taught, in a way that builds the student's ability to solve further problems on their own. The proposed order was followed almost exactly in the MoDP course syllabus.

Enström & Kann (2017) recommend pointing out variations in problem types when teaching algorithms. Dasgupta et al., (2008) in *Algorithms*, lists and illustrates common sub-problem types. These recommendations were implemented starting from Notebook 3 where the concept of sub-problem 'patterns' is introduced.

The work of Enström (2013) and (Kahney and Eisenstadt, 1982) on the importance of building a student's viable mental model of recursion influenced the emphasis put on recursive techniques throughout the course, and particularly in the first lessons.

The following sections briefly describe each lesson's learning goals and purpose.

3.4.1 *Notebook 0 – Introduction*

The purpose of this notebook is twofold: Introduce the student to the Jupyter notebook environment and the course structure, and then introduce dynamic programming and review recursive functions.

3.4.2 *Notebook 1 – Memoization*

Memoization is a core concept of dynamic programming. It is introduced in this notebook before the Fibonacci problem. This notebook also teaches the use of a decorator pattern to cleanly implement memoization.

3.4.3 *Notebook 2 – N'th Fibonacci Number*

The purpose of this notebook is to introduce the concept of overlapping sub-problems. The notebook also teaches some Jupyter notebook tricks for profiling code using magic commands.

3.4.4 *Notebook 3 – Maximum Weighted Independent Set on a Line*

This notebook introduces a problem that is simple to describe and follows smoothly from the almost trivial Fibonacci problem. The notebook introduces the step-by-step approach to solving any dynamic programming problem.

3.4.5 *Notebook 4 – Paths in a Grid*

This notebook is not in the scope of the project at the time of writing.

The purpose of this lesson is to practice the new concepts learnt in the previous lesson.

3.4.6 *Notebook 5- Longest Common Subsequence*

This lesson compares a top-down recursive solution to a bottom-up iterative solution to the same problem

3.4.7 *Notebook 6 – Longest Increasing Subsequence*

In this lesson the student learns how to strengthen the induction assumption to solve problems where the sub-problems are not instances of the original problem.

3.4.8 *Notebook 7 – Knapsack*

This notebook was not in the scope of the project at the time of writing.

This lesson introduces the first problems whose time complexity depends on the input's values (pseudo-polynomial time).

3.4.9 *Notebook 8 – Directed Acyclic Graphs*

This notebook was not in the scope of the project at the time of writing.

The lesson learning goal is to review all the problems previously seen and show the student how to see them from a high-level view as a topographically sorted graph.

4 METHODOLOGY

The course infrastructure and content were implemented in 6 weeks as part of a computer science graduate course in educational technology. At the two and then four-week milestones, surveys 1 and 2 respectively were sent to students in the same class. The surveys were answered anonymously. Since the responses to the two surveys were unrelated to each other, the results of each one could not be combined. Filling the survey was not a class requirement although participants received class participation points for doing so.

This form of evaluation had two advantages:

1. Critical feedback on the course content and structure was received in time for improvements to be made.
2. Fellow computer science students were likely to represent the MoDP target audience which was computer science students *before* taking a graduate course in algorithms.

Both surveys contained questions to ascertain whether the respondents were indeed representative of the MoDP target audience:

The survey questions can be seen in *Appendix 10.1: Course Need Survey Responses* and *Appendix 10.2: Course Evaluation Survey Responses*.

The purpose of survey 1 was:

1. To ascertain need for an introductory course in dynamic programming

2. To measure interest for the use of Jupyter platform in this context.
3. Receive early feedback on course accessibility and format.

The purpose of survey 2 was:

1. To measure concrete interest in MoDP i.e. "Will you take this course?"
2. To receive more feedback on course usability. i.e. "Can you see the quizzes?"

The surveys contained a mix of closed and open-ended questions.

Results were analysed qualitatively to categorize the answers and see how the pattern that emerged (Seers, 2012) answered the survey purpose.

5 RESULTS

The raw data can be viewed in *Appendix 10.1: Course Need Survey Responses* and *Appendix 10.2: Course Evaluation Survey Responses*.

5.1 The 1st Survey: Need

The first survey was answered by 54 respondents, 44 of whom said they reviewed the course materials.

Most of the respondents (38) have at least a first degree in computer science, electrical engineering or information technology. Only two respondents said they already took Graduate Algorithms (GA). 15 respondents agreed that they already have a solid foundation in dynamic programing. This still left a majority of the respondents representative of the course target audience: computer science majors who could benefit from an introductory course in dynamic programming.

Most respondent (70%) agreed that it is a good idea to prepare to take GA by learning dynamic programming.

Negative feedback after the first survey:

1. One user felt that video inside the Jupyter notebooks felt "clunky"
2. One user did not like the musical intro of the videos.
3. One user commented that the video (there was only one at that time) was "a little cluttered visually".

4. Over 1/5th of the respondents described difficulties navigating the notebooks. "As a user, I don't really understand where to start". "Could really use some help on how to navigate folders", "Can you add a readme on how to get started with Jupyter notebooks?"
5. One user could not access the notebooks at all: "The notebooks kept redirecting when I opened them"
6. A few users requested features: "Solution should be hidden until I'm ready to check my answer,",

Positive feedback after the first survey:

1. A few respondents indicated that they would take the course when it's finished: "Very useful project", "Cool. I will use this resource as preparation for the GA course", "Found them very useful."
2. Use of Jupyter notebooks: "Jupyter Notebook is my go-to technology for learning and using python."
3. Respondent also gave technical advice, such as zooming in when coding in videos.

In conclusion, the results of the 1st survey:

1. Did indicate a need for a course in dynamic programming.
2. Indicated that the Jupyter platform could be a problematic platform for delivering a course
3. Gave useful feedback which was incorporated in subsequent project development.

5.2 The 2nd Survey: Evaluation

The 2nd survey was answered by 31 respondents.

Only 3 respondents did not agree with the statement: "I understood how to navigate the course material". By the 2nd milestone, the notebooks were better organized, and usage instructions were clearer. One respondent wrote: "The front page provided very clear categories. The Jupyter work book also has clear flow to follow".

One respondent provided valuable feedback: "It wasn't clear if I had to go in lesson order. "

For technical reasons, users needed to run the notebooks in order to see all the videos and quizzes. This was not entirely clear in the instructions. Four respondents commented: "never really saw a quiz", " i didn't see video, do you mean the gifs? I saw gifs! " "the quizzes weren't working (intro lesson) ", " I didn't see anything about videos in the notebooks- did I miss something? "

The last question was to ascertain whether respondents would take the course. 74% of the respondent agreed or strongly agreed that they would bookmark the course, although some qualified their response by saying that they might not actually work through the course. One respondent remarked though that because of lack of time, the course would need to be proven effective:

> " If the course is proven effective via social proof, I would be likely to take it … [but] taking the entire course before I know its effectiveness is risky

And finally, some respondents requested that the project be available and that it continue, such as this comment:

> "Please continue to work on this project after this course. GA is considered the toughest course in the program, and anything which can make student's life easier will be highly appreciated."

In conclusion, the results of the 2nd survey:

1. Measured a moderate interest among computer science students in taking the finished course
2. Provided more valuable feedback which was incorporated into the final delivery.

6 LIMITATIONS

Conclusions about the effectiveness of teaching dynamic programming using Jupyter notebooks in general, and of the effectiveness of this course in particular, are limited in a few ways: Firstly, the evaluators were school colleagues which, due to selection and confirmation bias, makes it unreasonable to generalize their mostly positive responses to a broader audience.

Secondly, in this work, there was no attempt to compare teaching dynamic programming on the Jupyter notebook platform to teaching it on other platforms.

The course content at the time of evaluation was still in early stages of development and it was not possible to compare it for example, to a polished course on another more traditional platforms.

7 CONCLUSION

This paper has demonstrated the use of Jupyter notebooks as a potentially effective medium for teaching dynamic programming. Whether dynamic programming is truly more difficult than other concepts in algorithm design or not, the impetus for this project was to help to dispel this notion or at least help students overcome the difficulty. The peer survey results were enthusiastic, and many encouraged the project to continue beyond this study.

Although it is not possible to extrapolate the success of the MoDP prototype to any course developed on Jupyter notebooks, the platform does facilitate the presentation of the course material in a step-by-step manner. Jupyter notebooks with additional interactive elements added as described in this paper, allow students to experiment with, and practice designing dynamic programming algorithms.

8 FUTURE WORK

At the time of this paper's writing the project is in minimal viable product stage. The course content and supporting infrastructure are actively being expanded.

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10 APPENDICES

10.1 Course Need Survey Responses

This survey was given 2 weeks into the project when it was a working prototype. The survey questions were:

1. **Q1**. (choose one) The course is implemented as a series of Jupyter notebooks. Here's a link to the course GitHub repository. Click the binder link in the readme for an interactive version of the notebooks.
2. **Q2**. (short answer) Please write here feedback on the Jupyter notebooks if you viewed them. Video, quizzes, exercises, general look etc.
3. **Q3**. (agreement 5..1) Dynamic Programming is a difficult subject to master.
4. **Q4**. (short answer) How many OMSCS courses have you successfully completed so far?
5. **Q5**. (short answer) What is your educational background? What are your academic degrees and what are they in?
6. **Q6**. (choose multiple) This question refers to the OMSCS course Graduate Algorithms (GA). Check whichever choices are applicable to you (e.g. you may be retaking GA)
7. **Q7**. (agreement 5..1) Before taking GA, it's a good idea to prepare by learning dynamic programming before.
8. **Q8**. (agreement 5..1) I feel I have a solid foundation in dynamic programming algorithms

9. **Q9**. (agreement 5..1) I know a method for solving any dynamic programming problem
10. **Q10**. (short answer) Feedback on this survey or anything else you would like to share

These are the responses per respondent numbered 1-54 to the questions: Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10

1,I reviewed the course materials,Maybe give a brief overview on how to approach dynamic problems,5,7,Bachelors in Statistics,I have taken GA,,3,3,"Looks good so far, keep it up"

2,I reviewed the course materials,"The notebooks kept redirecting when I opened them. I'm not sure if I did something wrong, or if it is the notebooks running a script, but it happened numerous times. ",4,2,B.S. Business/HRM ; MBA - conc. Social Statistics; ,I have NOT taken GA,4,3,5,

3,I reviewed the course materials,Using empty cells for spacing is kind of produces kind of a weird look. ,4,1,BA in Computer Science and Environmental Studies,I have NOT taken GA;I will take GA in the future,3,4,4,

4,I reviewed the course materials,,5,4,"bachelors cs, ",I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,2,2,Your video filiming recording was excellent and punctual! Great job!

5,I did NOT review the course materials,,5,2,Bachelors in Computer Science,I have NOT taken GA,5,4,4,

6,I reviewed the course materials,Good start. I would recommend though in your GitHub to write another guide on setting up your environment so someone can follow along.,3,2,Information Technology for my BS,I have NOT taken GA,3,3,3,

7,I did NOT review the course materials,,5,7,Bachelor's in electronics and instrumentation,I have NOT taken GA,5,3,2,I think this is a great topic

8,I reviewed the course materials,Cool. I will use this resource as preparation for the GA course.,4,5,BS in electronic engineering,I have NOT taken GA,5,2,2,

9,I reviewed the course materials,there seemed to be some basic examples of recursion but not a lot of details/context,4,8,BA in Economics,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,4,3,4,

10,I reviewed the course materials,,3,5,,I have NOT taken GA,4,3,3,

11,I reviewed the course materials,The Launch icon for the Jupyter notebook is great! I have never heard of Binder but excited to know about it now.,5,9,I have a bachelors in Electrical Engineering and am about to finish up the OMSCS program after completing Educational Technology with a specification in Interactive Intelligence.,I have taken GA,5,4,3,Great survey and great material!

12,I reviewed the course materials,"good video, but clunky being embedded in jupyter",4,4,"BSc CS, MBA",I have NOT taken GA;My OMSCS specialization requires GA,3,4,3,

13,I reviewed the course materials,very informative,4,2,ba economics,I have NOT taken GA,4,1,4,n/a

14,I reviewed the course materials,"I did watch the video on Jupyter notebooks, it was a little cluttered visually. I think you may want to consider focusing on the design of the video.",4,7,"BS Psych, BA Criminology, JD (Law)",I have NOT taken GA,4,3,3,

15,I reviewed the course materials,"love it! At first with the videos I thought the music was distracting - but, then I realized how it made me more engaged and felt as though the lessons were more professional",5,7,"Undergrad - Math and Computer Science, Masters in Education & Social Change",I will take GA in the future;My OMSCS specialization requires GA,3,2,2,

16,I reviewed the course materials,good,3,0,MBA in Analytics and Technology. BBA in MIS,I have NOT taken GA,3,1,1,

17,I reviewed the course materials,"if you are using jupyter notebooks, running them with smaller input batches and presenting the output at each step would be useful",2,1,Undergraduate in IT,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,2,4,4,

18,I reviewed the course materials,I liked the interactive method of learning. Some videos were not working but I guess it will be updated later. I also liked the quiz and hint section.,4,6,Electronics and communication Engineering,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,4,2,3,N/A

19,I reviewed the course materials,,4,2,,I have NOT taken GA,4,4,4,

20,I reviewed the course materials,"It looks very interesting! As a user, I don't really understand where to start, though. Some sort of indicator or obvious ""CLICK HERE"" type of thing would be helpful",4,7,BS in Computer Science,I have NOT taken GA,3,4,2,

21,I reviewed the course materials,They look great.,2,6,BS Computer Science,None of the above,4,4,4,

22,I reviewed the course materials,"Intro music to dynamic programming video reminds me of a carnival ride, and reminds of clowns. I don't like clowns. ",4,6,BS in CS,I will take GA in the future;My OMSCS specialization requires GA,4,2,3,

23,I reviewed the course materials,,4,7,,I have NOT taken GA,3,3,2,

24,I reviewed the course materials,,4,1,Computer Engineering Bachelors,I have NOT taken GA,3,2,2,

25,I reviewed the course materials,I think some of the notebook might not be rendering properly in oo: \begin{itemize} \item one \item two \end{itemize},4,4,B. S Computer Engineering,I have NOT taken GA;I will take GA in the future,4,2,2,

26,I reviewed the course materials,"There a current error ""NameError: name 'create_multipleChoice_widget' is not defined"" in the Fibonnaci jupyter workbook, which should be cleaned up in the next checkin. The video looks good and gives the viewer a good overview of what to expect in your course.",4,8,BS in Electrical Engineering and Computer Science,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,2,2,N/A

27,I reviewed the course materials,"Is there a way to obscure the answers? Maybe in a separate file? Providing the answers within easy view hurts the learning process, IMO, because it's impossible to avoid.",4,7,Bachelors in Computer Science and Applied Math,I have NOT taken GA,,4,1,

28,I reviewed the course materials,It would be nice to have more directions on what to do/the exercises in the jupyter notebook itself,4,7,BS in CS,I have NOT taken GA,3,4,4,

29,I reviewed the course materials,"I liked the jupyter notebooks, for some reason it was a bit laggy at first to load some items, but could be a browser problem. Good video and appreciated the set up",4,1,BA in Statistics & Actuarial Mathematics with minor in Computer Science ,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,4,3,2,

30,I reviewed the course materials,Amazing take on the detailed video.,5,5,Bachelor of Science in Computer Science,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,1,2,Very useful project

31,I reviewed the course materials,,4,8,,I have NOT taken GA,,3,3,

32,I reviewed the course materials,Videos - Animations or video recordings include scratch padding can go a long way since the topic is complex.,5,6,"Bachelor of Technology, Electronics but working as software engineer for the last 15 years",I will take GA in the future,5,3,2,

33,I reviewed the course materials,Jupyter Notebook is my go to technology for learning and using python.,4,5,Bachelors in Electorinics and Communciation,I have NOT taken GA,5,3,2,

34,I reviewed the course materials,"You should include more directions on your README in the repo: The structure of your repo (where your videos, quizzes, exercises are located), how to install and run your examples, what time is suggested to spend on each lesson. Your intro video looks promising. However the content of your repo at this moment is little too primitive to offer any concrete feedback.",3,4,BS degree in Computer Science,I have taken GA;My OMSCS specialization requires GA,2,4,1,

35,I reviewed the course materials,It looks good so far; comprehensive and well covered,4,2,"BS in CS, BA in Religion",I have NOT taken GA,4,2,2,DP is a hard topic to cover. Probably worth investing more personal time to learn effectively

36,I did NOT review the course materials,,5,3,"Engineering degree in Biotechnology, MBA in Finance",I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,1,1,

37,I reviewed the course materials,Found them very useful. ,5,5,Bachelors in CS,I will take GA in the future,5,2,4,"I really liked the course, My own course in

EDTECH uses the same approach of blended learning with video and jupyter notebooks via binder: https://github.com/yogeshmpandey/M4DT"

38,I reviewed the course materials,"Can you add a readme on how to get started with Jupyter notebooks. I did figure out, but it is easy if you include it in your repo",4,8,Bachelor in Computer Science,I have NOT taken GA,3,2,2,

39,I reviewed the course materials,the notebooks look great. Would love to see how you render them and how we can run them real-time.,5,7,bachelor of engineering in computer science,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,2,2,

40,I reviewed the course materials,,4,5,,I have NOT taken GA,5,3,4,

41,I reviewed the course materials,quizzes,4,7,,I have NOT taken GA,4,4,3,

42,I reviewed the course materials,,4,7,engineering,I have NOT taken GA,4,2,2,

43,I did NOT review the course materials,,3,5,computer science,I will take GA in the future,4,2,2,Good survey

44,I reviewed the course materials,,4,5,phd engineering,I have NOT taken GA,4,4,3,

45,I reviewed the course materials,I'd try to zoom in on the jupyter cells if you can,4,5,Bachelor's in Mechanical Engineering,I have NOT taken GA,5,2,4,

46,I reviewed the course materials,,,4,BS Computer science,I have NOT taken GA,,4,4,

47,I did NOT review the course materials,,,4,Bachelor's in Computer Science,I have NOT taken GA,,2,2,

48,I reviewed the course materials,"The videos and writing exercises in jupyter notebook looks good. I found one solution to the exercises, Are there alternative solutions possible for the same problem?",5,7,Bachelor of Engineering in Computer Science,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,5,2,1,n/a

49,I did NOT review the course materials,,4,4,Bachelors degree in Computer Science,I have NOT taken GA;I will take GA in the future,5,3,3,

50,I reviewed the course materials,"using binder: Could really use some help on how to navigate folders and the general path for the lessons to come.Excercise could use some formatting or an image to easily show that it's time for a coding excercise as opposed to new material. Also it would help to have a quick run-down/resource for how to use the notebook. Also, minor issue had to select kernel to be python3 manually before it would work. Solution should be hidden until I'm ready to check my answer, too tempting just to copy it.",5,5,BS Computer engineering,I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,4,4,2,"I wish I got some reward for doing a problem correctly. Even something super small like a unit test after each problem that spits out ""Nice job rock star!"" if the answer is right."

51,I did NOT review the course materials,,4,5,,I have NOT taken GA,4,2,2,

52,I did NOT review the course materials,,4,4,Master in Information Techonogy and Management,I have NOT taken GA,4,2,2,N/A

53,I did NOT review the course materials,I don't know much of what the content should be since I have not taken GA. But overall it looks good.,5,5,BS in Mechanical Engineering,I have NOT taken GA,5,1,2,

54,I did NOT review the course materials,,5,5,"Received a BS in information systems. Also took a handful of computer science courses prior to being in GA OMSCS program, courses including computer organization, data structures, discrete mathematics, linear algebra.",I have NOT taken GA;I will take GA in the future;My OMSCS specialization requires GA,4,2,2,

10.2 Course Evaluation Survey Responses

This survey was given 4 weeks into the project when some course sections were complete. The survey questions were:

1. **Q1**. (choose one) The portal to the course is this GitHub repo. Only take this survey if you have reviewed the course.
2. **Q2**. (short answer) As the course is still in development, please enter the date (e.g. Saturday, July 18) so I know which version of the course you viewed.
3. **Q3**. (agreement 5..1) I understood how to navigate the course material. (e.g. you knew where to start)

4. **Q4**. (short answer) Optional: qualify your answer above
5. **Q5**. (choose multiple) Check whichever parts of the course you were able to access:
6. **Q6**. (short answer) Optional: Additional feedback on accessibility of notebooks, videos, quizzes, code etc.
7. **Q7**. (choose one) When will you be taking the course OMSCS Graduate Algorithms?
8. **Q8**. (agreement 5..1) I will be bookmarking the course link to return and take the complete course
9. **Q9**. (short answer) Optional: Explain why or why not you will take this course (e.g. it might be a good course, but you have no need to learn dynamic programming)
10. **Q10**. (short answer) Optional: Anything else you would like to add?

These are the responses per respondent numbered 5-35 to the questions Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10. The first four responses were empty because of a mistake in survey publishing and so were discarded.

5,I confirm that I viewed the course,July 14,4,,"I was able to load the notebooks;I was able to watch video;I was able to view code solutions;I could view formulas, text and images",,Most probably some other future semester (I need it to graduate),4,,

6,I confirm that I viewed the course,Tuesday July 14,3,Not used to running jupyter notebooks,"I was able to load the notebooks;I was able to watch video;I was able to run the quizzes;I was able to view code solutions;I could view formulas, text and images",View solution part is a great feature.,I already took/am taking GA,3,"Everything looks good, I already took the class though.","Keep it up, loving the integration of jupyter notebooks"

7,I confirm that I viewed the course,"Wednesday, July 15",4,,"I was able to load the notebooks;I was able to watch video;I was able to run the quizzes;I was able to view code solutions;I could view formulas, text and images",easy to understand solutions,Most probably some other future semester (I need it to graduate),5,as it might be useful to complete GA,

8,I confirm that I viewed the course,July 15th,4,,I was able to watch video;I was able to view code solutions,,n/a,4,Dynamic programming is always helpful,n/a

9,I confirm that I viewed the course,thursday july 16,5,,I was able to watch video,,Most probably some other future semester (I need it to graduate),4,,

10,I confirm that I viewed the course,"Saturday, July 14",3,,"I could view formulas, text and images",,n/a,3,,

11,I confirm that I viewed the course,"Thursday, July 16",5,,"I was able to load the notebooks;I was able to watch video;I was able to view code solutions;I could view formulas, text and images",,Most probably some other future semester (I need it to graduate),4,,this is really awesome - great job! as a teacher i would LOVE something like this especially now having to do online learning

12,I confirm that I viewed the course,"Friday, July 17",5,,I was able to load the notebooks,,Most probably some other future semester (I need it to graduate),4,I heard GA is notorious for challenging due to the difficulty of mastering DP. I would like to study DP in advance.,

13,I confirm that I viewed the course,Thursday 16th,4,,"I was able to load the notebooks;I was able to watch video;I was able to view code solutions;I could view formulas, text and images",never really saw a quiz,Most probably some other future semester (I need it to graduate),3,"Pretty much what you just said, but we will see when I get closer to taking GA",

14,I confirm that I viewed the course,"Thursday, July 16",4,,I was able to load the notebooks;I was able to watch video,,n/a,3,I take AI next sem. So I'll be visiting this since AI seem to have DP and DP is new for me,

15,I confirm that I viewed the course,July 16,5,,"I was able to load the notebooks;I was able to watch video;I was able to run the quizzes;I was able to view code solutions;I could view formulas, text and images",,n/a,5,"I won't be taking the course, but I'm bookmarking this anyway. Unbelievable amount of work - nice job!","I didn't survey everything in depth, but I noticed 2 small things on the readme. Typo in ""Does dynamic progrmming"" and the markdown link formatting is a little broken under this header https://github.com/rachelyeshurun/magic-of-dynamic-programming#behind-the-scenes"

16,I confirm that I viewed the course,"7/16, commit 3385b5b",5,,I was able to load the notebooks;I was able to view code solutions,,I already took/am taking GA,4,,

17,I confirm that I viewed the course,July 16,4,,"I was able to load the notebooks;I was able to watch video;I was able to run the quizzes;I was able to view code solutions;I could view formulas, text and images",,Most probably some other future semester (I need it to graduate),4,It is too hard for me to study this course,

18,I confirm that I viewed the course,"Friday, July 17th",4,"I can follow along, but I'm less familiar with the material!","I was able to load the notebooks;I was able to run the quizzes;I was able to view code solutions;I could view formulas, text and images","i didn't see video, do you mean the gifs? I saw gifs!",n/a,2,"no need, but i'll know where to go if i need it!",great job!!

19,I confirm that I viewed the course,"Saturday, July 18",4,,"I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,Most probably some other future semester (I need it to graduate),4,,The project idea is great. I was able to navigate the repository easily. Best wishes for the final deliverable.

20,I confirm that I viewed the course,July 19,4,,I was able to watch video (in the notebooks),,Most probably some other future semester (I need it to graduate),4,,

21,I confirm that I viewed the course,July 19,5,The front page provided very clear categories. The Jupyter work book also has clear flow to follow,I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks),,Most probably some other future semester (I need it to graduate),5,The video explains the concept pretty clear. It is much easier to understand than other courses,

22,I confirm that I viewed the course,"Sunday, July 19",2,It wasn't clear if I had to go in lesson order.,I was able to load the notebooks;I was able to view the code solutions (in the notebooks),Everything was easy to access. I was mostly just looking at the format and structure.,Fall 2020,2,I already know dynamic programming.,Great job!

23,I confirm that I viewed the course,"Sunday, July 19",4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,n/a,5,II doesnt have GA mandatory. So may skip it due to the

complexity of the topic. Additionally I learn it out of my liking outside.,Very good attempt.

24,I confirm that I viewed the course,July 19,4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,n/a,5,To refresh my understanding,

25,I confirm that I viewed the course,Monday July 20,4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",the quizzes weren't working (intro lesson),n/a,4,,

26,I confirm that I viewed the course,July 20,4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,Most probably some other future semester (I need it to graduate),4,,"Please continue to work on this project after this course. GA is considered the toughest course in the program, and anything which can make student's life easier will be highly appreciated."

27,I confirm that I viewed the course,"Monday, July 20",4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,n/a,2,"GA isn't required for my specialization and the course isn't relevant in my work, though it looks interesting!",

28,I confirm that I viewed the course,July 21,4,,I was able to load the notebooks;I was able to watch video (in the notebooks),,n/a,4,I would like to take this course as I have always found it challenging to do dynamic programming.,You have done a great job with the course creation.

29,I confirm that I viewed the course,July 21,4,,I was able to load the notebooks;I was able to watch video (in the notebooks),,I already took/am taking GA,5,I have to take this course as its part of my specialization,"Really nice course, as someone who is taking GA this semester it would have been a convenient resource to have when DP was being covered"

30,I confirm that I viewed the course,July 22,5,it's laid out numerically.,"I was able to load the notebooks;I was able to run the quizzes (in the notebooks);I could view formulas, text and images (in the notebooks)",I didn't see anything about videos in the notebooks- did I miss something?,Most probably some other future semester (I need it to graduate),3,I don'r know where I'll be a year from now code wise,

31,I confirm that I viewed the course,"Wednesday, July 22",4,Readme page with table of contents and instructions were very helpful.,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",N/A,Most probably some other future semester (I need it to graduate),4,I am interested in taking GA and this course looks very interesting,Great job. I hope you can give access to this in future too.

32,I confirm that I viewed the course,"thursday, July 23",4,,"I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks);I was able to view the code solutions (in the notebooks);I could view formulas, text and images (in the notebooks)",,Most probably some other future semester (I need it to graduate),4,,

33,I confirm that I viewed the course,July 24,4,The documentation on Github makes navigation clear,"I was able to load the notebooks;I was able to watch video (in the notebooks);I could view formulas, text and images (in the notebooks)",,Most probably some other future semester (I need it to graduate),4,"Limited time. If the course is proven effective via social proof, I would be likely to take it because it was developed by a current GT student in preparation for the same class that I'm taking. But taking the entire course before I know its effectiveness is risky.",

34,I confirm that I viewed the course,7/26,4,,I was able to load the notebooks;I was able to watch video (in the notebooks);I was able to run the quizzes (in the notebooks);I was able to view the code solutions (in the notebooks),,n/a,4,,

35,I confirm that I viewed the course,26 July,4,,I was able to watch video (in the notebooks),,n/a,4,Complicated course,Algorithm based classes are tough and need precursor